Serial/Patent.No.: 09/914,928 Filing/Issue Date: 9/6/01
Applicant: Loick Verger et al.
Title: X-RADIATION IMAGERY DEVICE AND PROCESS FOR MAKING THIS DEVICE

TRP Docket No.: 034299-000346 Atty/Secty Initials: REK/MA/ /cd
Date Mailed: 11-7-03 Docket Due Date:

The following has been received in the U.S. Patent & Trademark Office on the date stamped hereon:

- ☒ Amendment/Response (12 pgs.)
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- ☐ Declaration & POA (_____ pgs.)
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- ☐ Drawings (informal):
  _____ # of sheets includes _____ figures
- ☒ Other:
  Limited Recognition Under 37 CFR §10.9(b)
- ☒ IDS & PTO 1449 (4 pgs.)
- ☒ 1 Pieces of Prior Art Enclosed
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- ☐ Submission of Formal Drawings:
  _____ # of sheets includes _____ figures
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Patent Code: 1253/1806
Client/Matter # 34299 - 346

Docket No. 034299-000346

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICANT:	Loick Verger et al.
SERIAL NO.:	09/914,346
FILING DATE:	September 6, 2001
TITLE:	X-RADIATION IMAGERY DEVICE AND PROCESS FOR MAKING THIS DEVICE
EXAMINER:	Christine Sung (Tel. No.: (703) 305-0382) (Fax No.: (703) 308,7722)
ART UNIT:	2878

CERTIFICATE OF MAILING

I hereby certify that this paper is being deposited with the United States Postal Service as First Class Mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313 on the date printed below:

Date: 11-7-03 Name: Carol Diez
Carol Diez

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INFORMATION DISCLOSURE STATEMENT

Each item of information listed in the attached FORM PTO-1449, for which a copy of each is attached, may be material to the examination of the above-identified application and is, therefore, submitted in compliance with the duty of disclosure defined in 37 CFR §§ 1.56, 1.97 and 1.98. The Examiner is requested to make these items of official record in this application.

This Information Disclosure Statement under 37 CFR §§ 1.56, 1.97 and 1.98 is not to be construed as a representation that a search has been made, that additional information material to the examination of this application does not exist, or that any one or more of these items constitutes prior art.

I

This statement is filed pursuant to:

( ) 37 C.F.R. § 1.97(b).
This information disclosure statement is filed either (1) within three months of the filing date of a national application other than a continued prosecution application under §1.53(d); (2) within three months of the date of entry of the national stage as set forth in 37 C.F.R. § 1.491 in an international application; (3) before the mailing date of a first office action on the merits, or (4) before the mailing of a first office action after the filing of a Request for Continued Examination under 37 C.F.R. § 1.114, whichever event occurs last.

Accordingly, this information disclosure statement requires no fee and no certification.

(X) 37 C.F.R. § 1.97(c).
This information disclosure statement is filed after the period specified in 37 C.F.R. § 1.97 (b), but before the mailing date of either (1) a final action under 37 C.F.R. § 1.113; (2) a notice of allowance under 37 C.F.R. § 1.311; or (3) an action that otherwise closes prosecution in the application.

Accordingly, this information disclosure statement requires either the fee specified in 37 C.F.R. § 1.17 (p) for submission of an information disclosure statement under 37 C.F.R. § 1.97 (c) ($180); or a certification according to 37 C.F.R. § 1.97 (e).

( ) 37 C.F.R. § 1.97(d).
This information disclosure statement is filed after the period specified in 37 C.F.R. § 1.97 (c).

Accordingly, this information disclosure statement requires the fee specified in 37 C.F.R. § 1.17 (p) to consider an information disclosure statement under 37 C.F.R. § 1.97(d) ($180), and a certification according to 37 C.F.R. § 1.97(e).

If this statement crosses in the mail with an office action, or is otherwise not in the indicated category of 37 C.F.R. § 1.97, it is respectfully requested that this statement be treated in the next appropriate category and made of record. To the extent required, please treat this paper as a conditional petition for acceptance of the information disclosure statement.

II

( ) No fee is due.

(x) The fee specified in 37 C.F.R. § 1.17(p) for submission of an information disclosure statement under 37 C.F.R. § 1.97(c) is enclosed ($180).

Please charge any additional required fee or credit any overpayment to our deposit account number 50-1698. An additional copy of this page is enclosed.

III

Pursuant to 37 C.F.R. § 1.97(e) , I certify:

(X) No certification is necessary.

( ) (1) Each item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the statement.

( ) (2) No item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, or, to my knowledge after making reasonable inquiry, was known to any individual designated in 37 C.F.R. § 1.56(c), more than three months prior to the filing of the statement.

Respectfully submitted,
THELEN REID & PRIEST LLP

Dated: November 7, 2003

Masako Ando
Limited Recognition Under 37 CFR §10.9(b)

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Form PTO 1449 (Rev. 2-32) U.S. Department of Commerce Patent and Trademark Office	Atty. Docket No. 034299-000346	Serial No. 09/914,346
Information Disclosure Statement by Applicant	Applicant: Loick Verger et al.	
(Use several sheets if necessary)	Filed: September 6, 2001 Group: 2878	

U.S. Patent Documents

Init.		Document No.	Date	Name	Class	Subclass	Filing Date

Foreign Documents

Init.		Document No.	Date	Country	Class	Subclass	Translation Yes	Translation No

Other Documents (Including Author, Title, Date, Pertinent Pages, etc.)

		M. Campbell et al., "Readout For A 64x64 Pixel Matrix With 15-Bit Single Photon Counting", Nuclear Science Symposium, Albuquerque, November 12, 1997,

Examiner	Date Considered

Examiner: Initial if citation considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include a copy of this form with the next communication to applicant.

3

L. Verger

Readout for a 64 x 64 Pixel Matrix with 15-bit Single Photon Counting*

M. Campbell, E. H. M. Heijne, G. Meddeler[1], E. Pernigotti[2], W. Snoeys.
CERN 1211 Geneva 23, Switzerland,

Abstract

A single Photon Counting pixel detector readout Chip (PCC) has been derived from previous work in the CERN RD19 collaboration for particle physics tracking devices, recently developed for high energy physics experiments. The readout chip is a 64 x 64 matrix of identical 170μm x 170μm cells. It is to be bump-bonded to an equally segmented 1 cm^2 matrix of semiconductor sensors, e.g. Si or GaAs. Each readout cell comprises a preamplifier, a discriminator and a 15-bit counter. The input noise is 170 e- rms. At the lowest nominal threshold of 1 400 e- (5.1 keV in Si) the cells exhibit a threshold distribution with a spread before adjustment of 350 e- rms. Each cell has a 5-bit register which allows masking, test-enable and 3-bit individual threshold adjust. After adjustment the threshold spread is reduced to 80 e- rms. Absolute calibration of the electrically measured equivalent charge can be done once the readout chip is bump-bonded to a detector.

I. INTRODUCTION

Hybrid pixel detectors have evolved rapidly in the field of high energy physics. In particular the RD19 collaboration at CERN has developed 3 generations of pixel readout chips [1][2][3][4]starting with the 'LAA' prototype chip[1] with 9 x 12 pixels and culminating in the recent LHC1/Omega3 chip which contains 2 032 pixels in an array of 16 x 127[4]. In the last two generations large multi-chip systems have been deployed successfully in high energy physics experiments. All throughout these developments γ-ray sources have been used as a means of calibrating the input charge and hence the threshold of the individual pixels. Clearly such devices could be used for γ-ray imaging and in several studies the potential for single particle counting pixel detectors with Si or GaAs has been put in evidence[5][6][7]. There were a number of limitations to the use of these devices for imaging. The readout architecture implemented in the pixel cells is tuned to the high energy physics environment, delaying the detected signals and requiring an

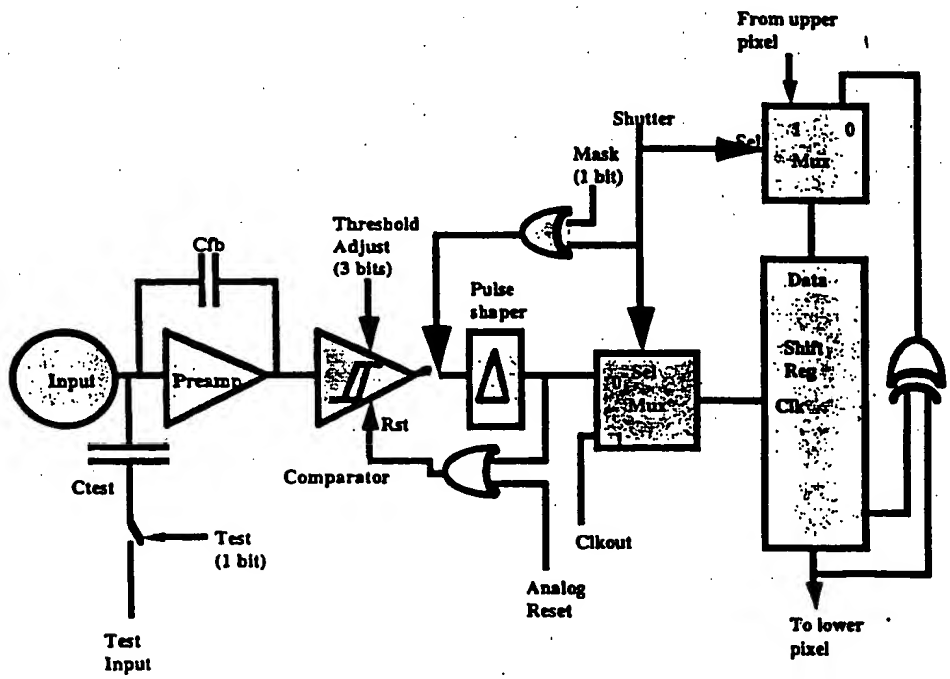

Figure 1: A block diagram of the pixel cell.

*This chip was developed as part of the Medipix project, a common development between CERN, University of Freiburg, University of Glasgow and INFN, Pisa (see Acknowledgments)

[1] Now with Nikhef, Amsterdam, The Netherlands and UC Santa Cruz. [2] Now with INFN, Pisa, Italy.

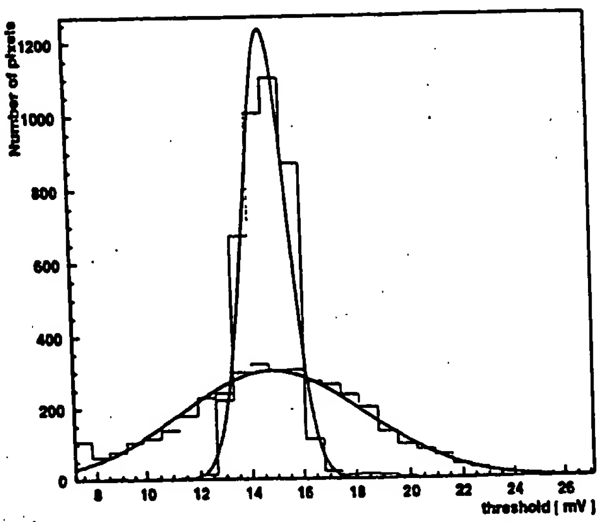

Figure 3: The distribution of thresholds on the chip. The mean threshold is around 15 mV corresponding to 1 400 e-. The variation is 350 e- rms prior to adjustment and 80 e- rms after adjustment.

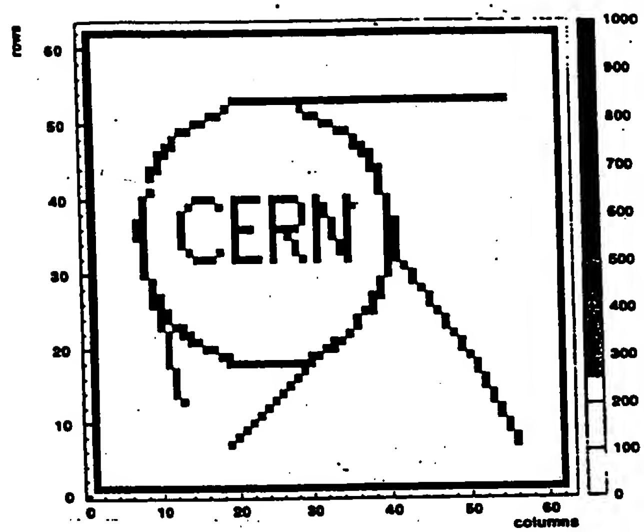

Figure 4: Results of a data acquisition using a test pattern corresponding to the CERN logo. This chip was pulsed 1 000 times. Only one noisy pixel is perceptible.

counting rate per pixel. Pixels could be pulsed at a rate of up to 2 MHz without loss of counts. A further test was carried out on the imaging capabilities of one chip. The average threshold was fixed at 2 250 e- without any local threshold adjustment. All of the pixels were unmasked and a test pattern of the CERN logo was introduced. With an open shutter time of 500 ms the chip was pulsed 1 000 times with an input signal of 3 300 e-. The result is shown in Figure 4. Noise in the pixels was negligible.

V. Conclusions and Further Work

A 4 096 cell pixel readout chip has been presented which when bump-bonded to a detector can be used for imaging γ-ray photons and other particles. The threshold of each pixel can be adjusted individually. Wafer probing is being performed at present for selection of Known Good Die prior to bump-bonding. The chip will be bump-bonded to both Si and GaAs detectors. Adoption of sub-micron CMOS technologies will allow to obtain similar or better performance within a smaller pixel size as well as a variety of additional features depending on the specific application.

VI. Acknowledgments

We gratefully acknowledge the collaboration and financial support of our partners in the Medipix project. In particular K. Smith and collaborators of the University of Glasgow, J. Ludwig and collaborators of the University of Freiburg and A. Stefanini and collaborators of the INFN, Pisa. G. Magistrati of Laben S.p.A., Milano provided the VME-based readout system and M. Conti and collaborators of the INFN, Napoli provided software for the readout system. Several people contributed to the testing of the chip. In particular P. Delogu, P. Maestro and S. Stumbo of INFN, Pisa, J. Watt of the University of Glasgow and B. Mikulec participating in the Austrian fellowship program at CERN.

VII. References

[1] M. Campbell et al., "A 10 MHz CMOS front-end for direct readout of pixel detectors," *Nucl. Instr. and Meth.* A 290 (1990) 149.

[2] F. Anghinolfi et al., "A 1006 element hybrid silicor pixel detector with strobed binary readout," *IEEE Trans Nucl. Sci.* NS-39 (1992) 654.

[3] M. Campbell et al., "Development of a pixel readou chip compatible with large area coverage," *Nucl. Insti and Meth.* A 342 (1994) 52.

[4] E. H. M. Heijne et al., "LHC1: a semiconductor pixe detector readout chip with internal, tunable dela providing a binary pattern of selected events," *Nuc Instr. and Meth.* A 383 (1996) 55.

[5] C. Da Via', "Semiconductor pixel detectors for imagin applications," PhD Thesis University of Glasgov Scotland and CERN, Geneva, Switzerland (1997).

[6] C. Da Via' et al., "Gallium arsenide pixel detectors f medical imaging," *Nucl. Instr. and Meth.* A 395 (199 148.

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[8] P. Horowitz and W. Hill., "The Art of Electronic: Cambridge University Press (1980) 438.

[9] P. Fischer et al., "A counting pixel readout chip imaging applications," submitted to *Nucl. Instr. a Meth.A* (1997).

READOUT for a 64 x 64 PIXEL MATRIX with 15 - bit SINGLE - PHOTON COUNTING

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Erik H.M. HEIJNE, Gerrit MEDDELER,
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CERN ECP Division

'Medipix' Collaboration
CERN, Freiburg, Glasgow, INFN Pisa

Nuclear Science Symposium
Albuquerque
12 November 1997

PHOTON COUNTING CHIP

SUMMARY

CELL 170 μm x 170 μm
- 400 transistors

MATRIX 64 x 64 CELLS
- sensitive area 1 cm^2

CONTINUOUSLY SENSITIVE FRONTEND
- response time 150 ns

ADJUSTABLE THRESHOLD
- spread 80 e- rms

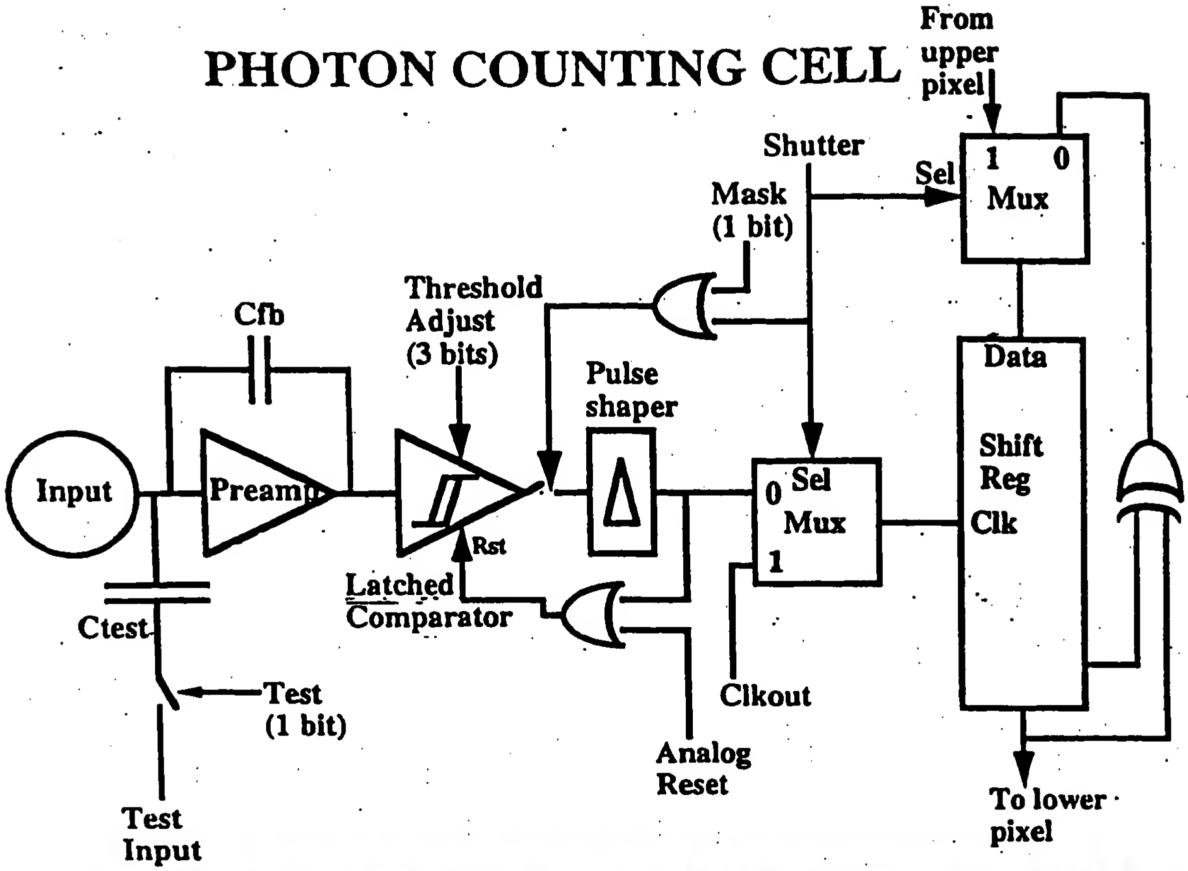
SUMMING IN PIXEL
- 15 bit counter

EXTERNAL SHUTTER SIGNAL
- static logic allows long integration times

INDIVIDUAL CELL ADDRESSED for TEST-SIGNAL and MASKING
- test patterns, no noise

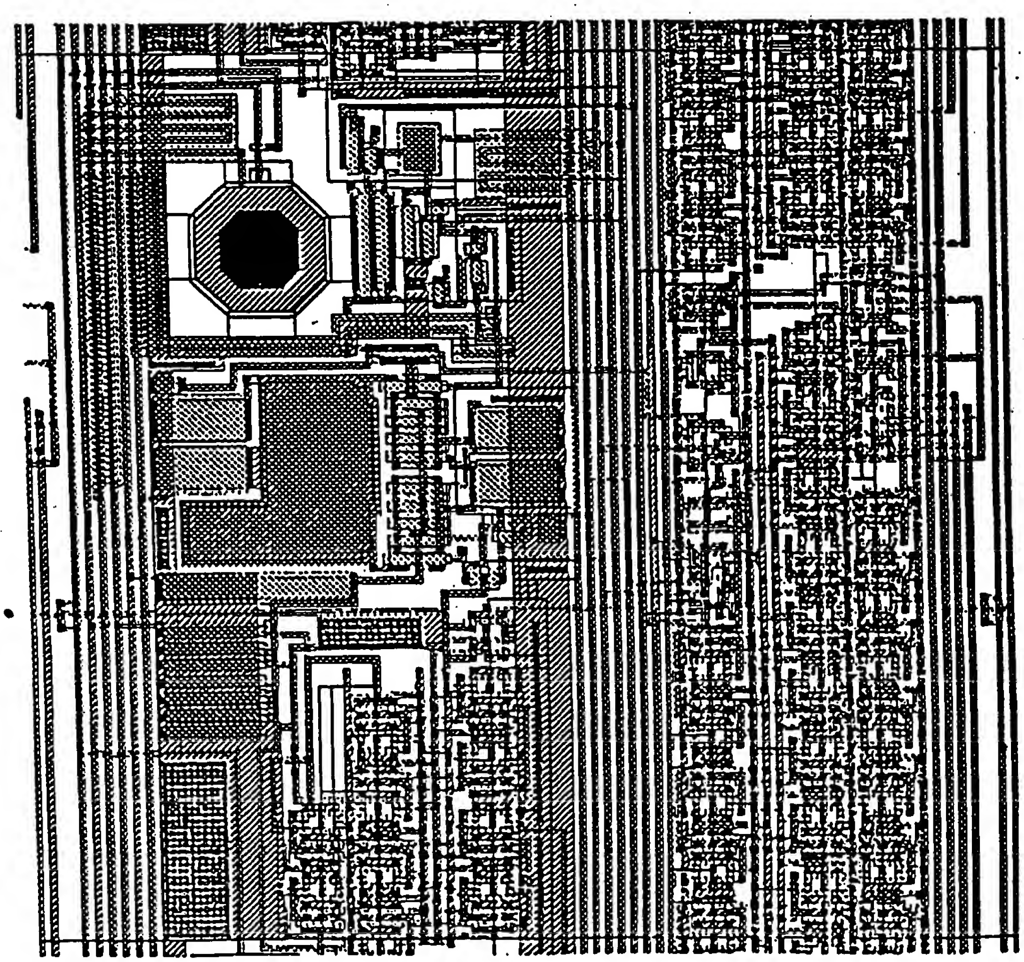
based on RD19 development

PHOTON COUNTING CELL

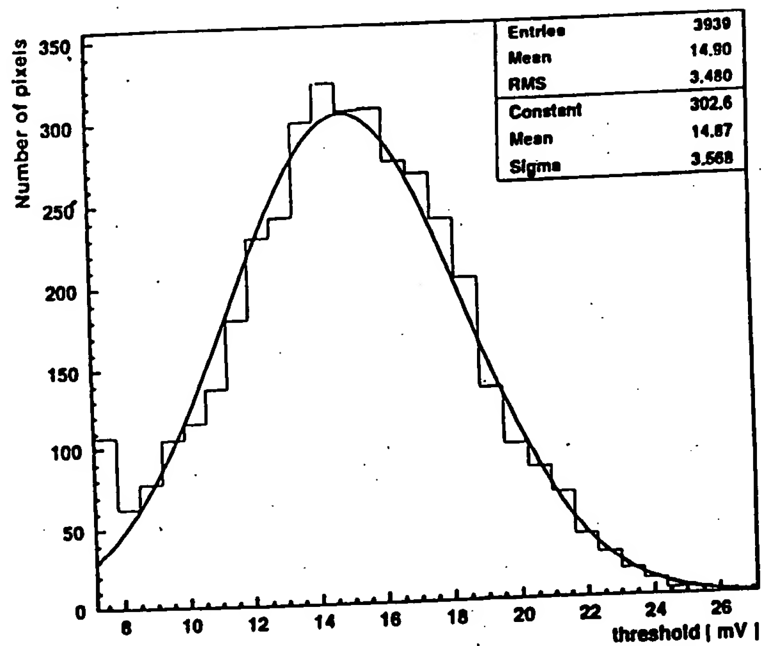


170 μm

~400 trans.



PCC 64x64 CELLS

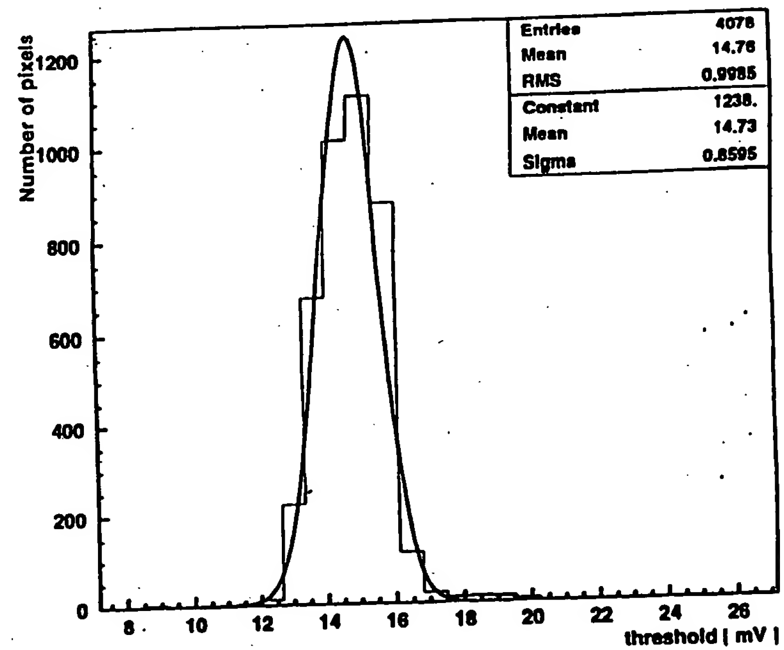


Threshold mean 1 400e-

Threshold variation 350e- unadjusted

→ INTERNAL ADJUSTMENT USING 3-BIT REGISTER

PCC 64x64 CELLS



Threshold mean 1 400e-

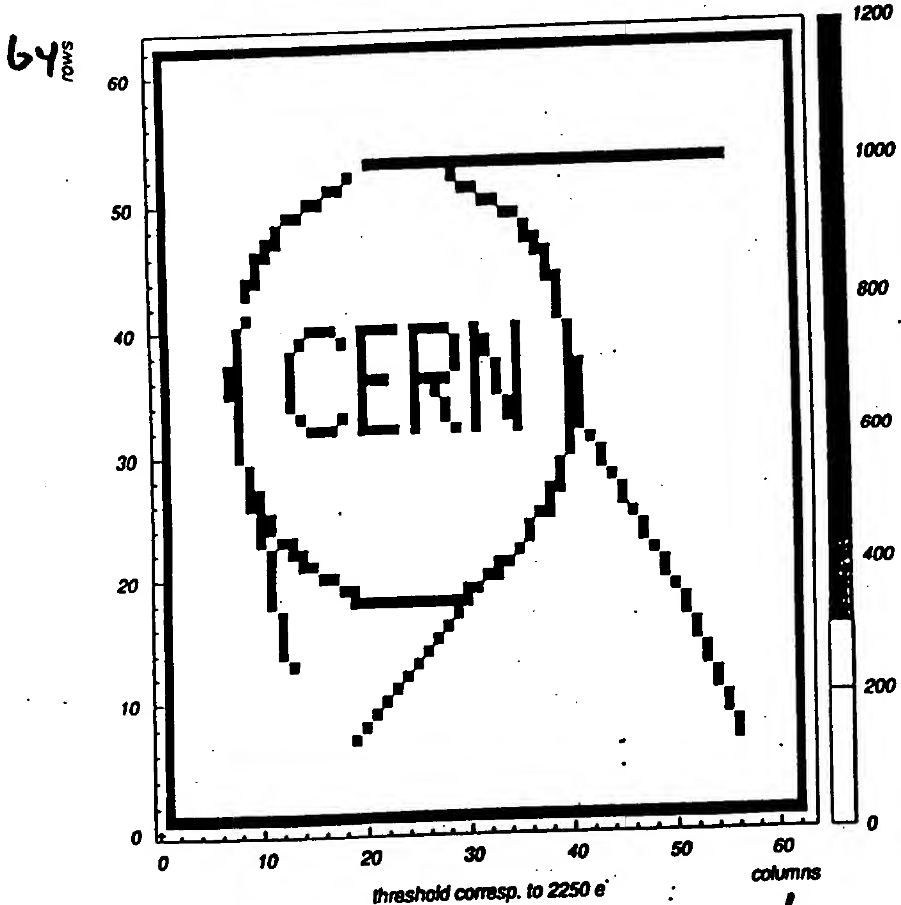
Threshold variation 350e- unadjusted
80e- adjusted

3-BIT DIGITAL ADJUST IN EACH CELL

MICHAEL CAMPBELL
ELENA PERNIGOTTI et al.

PHOTON COUNTING CHIP

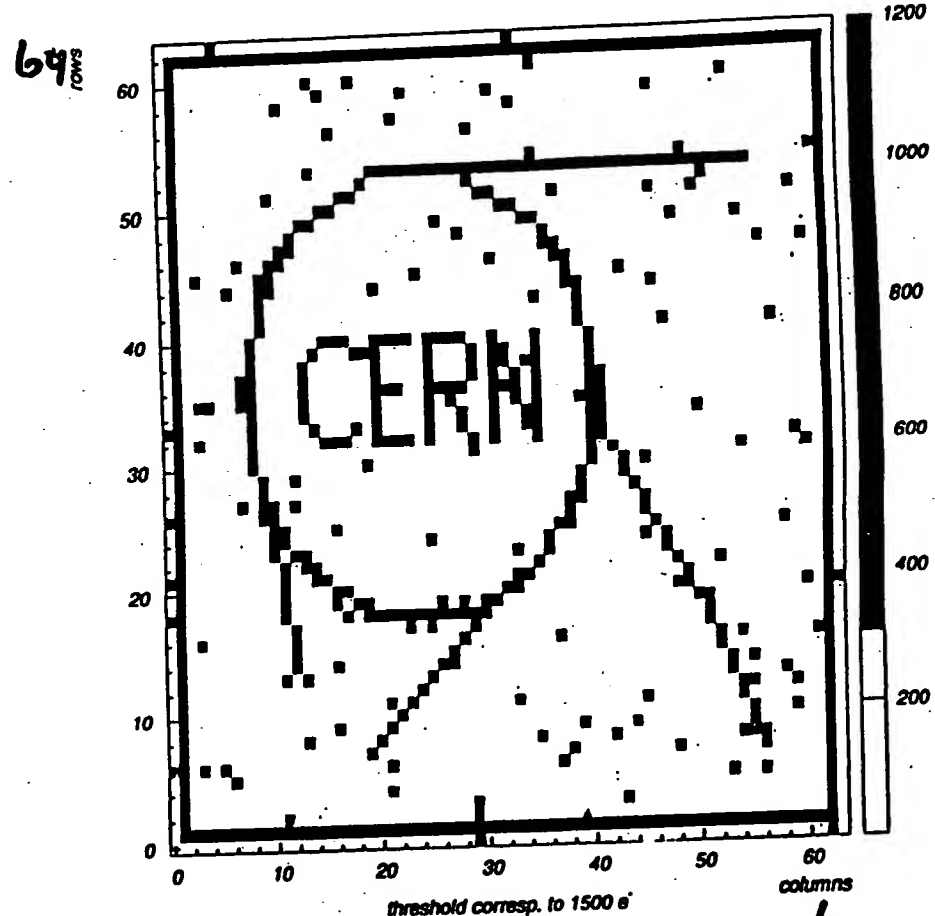
TEST PULSES 1000 x
NO MASKING APPLIED, ALL 4096 CELLS



THRESHOLD ~2250 e⁻ 8.2 keV

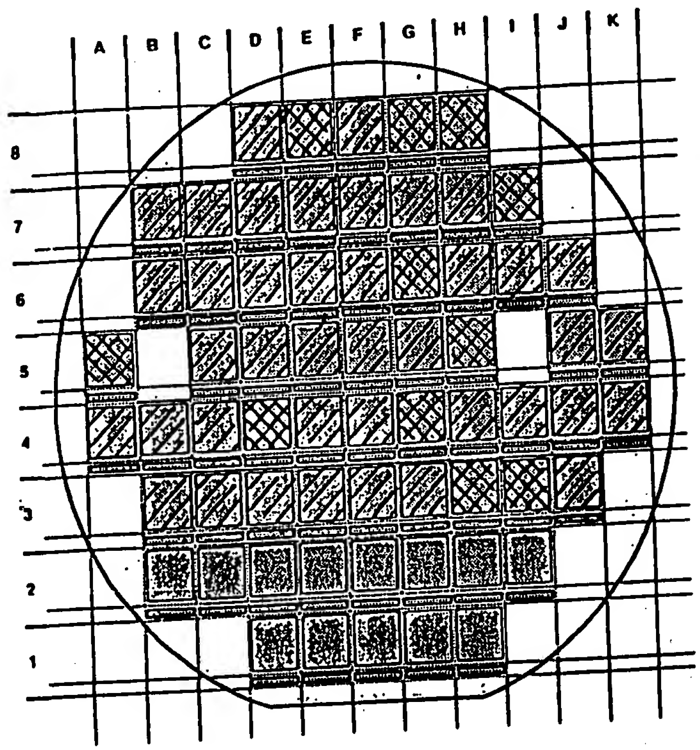
PHOTON COUNTING CHIP

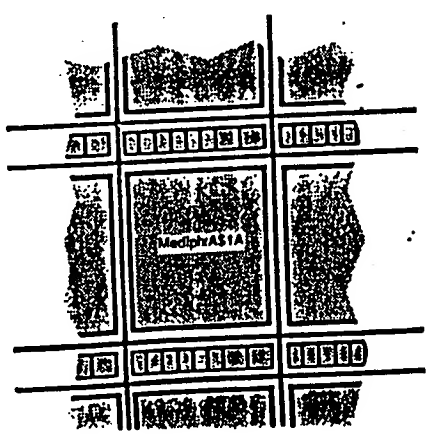
TEST PULSES 1000 x



THRESHOLD ~1500 e⁻ 5.5 keV

WAFER PROBING





Cotes des découpes

PHOTON COUNTING CHIP

FURTHER STEPS

PROBE TEST WAFER
- Known Good Die

BUMPING & BONDING
- GaAs & Si sensor chips
- Multi Chip Array

SUBMICRON DESIGN
- Smaller pixel cell
- Multiple metal layers

---> **BETTER DECOUPLING**